Atmautluak Hazard Impact Assessment

June 2010

Prepared for

The Atmautluak Traditional Council

Prepared by

WHPacific

with

SHANNON & WILSON, INC.

This assessment is funded by the Alaska Climate Change Impact Mitigation Program which was established by Alaska's Twenty-Fifth Legislature. The preparation of this assessment is funded by a grant from the Alaska Department of Commerce, Community and Economic Development, Division of Community and Regional Affairs. The views expressed herein are those of the authors and do not necessarily reflect the views of the State of Alaska or any of its sub-agencies.

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Letter of Approval

Atmautluak Traditional Council

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November 4, 2010

To whom it may concern:

The Atmautluak Traditional Council recognized the need to make informed decisions about future planning and the long term sustainability for the community. To that end, they hired WHPacific and subconsultant Shannon & Wilson to perform a Hazard Impact Assessment for the community of Atmautluak. The focus of this study is natural hazards, particularly those related to the impacts of climate change.

On October 21, 2010 the Atmautluak Traditional Council read and reviewed the *Atmautluak Hazard Impact Assessment* report. Recognizing the potential threat of climate change to the community, it is the Council's wish to be proactive in addressing potential hazards before they occur. The Council finds the assessment of potential impacts presented in the *Atmautluak Hazard Impact Assessment* to be both accurate and useful and accepts this report as an approved planning document for the community of Atmautluak.

Sincerely,

Nicholai Pavilla Sr. – Vice President

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Chapter 1 : Introduction

The Atmautluak Traditional Council recognized the need to make informed decisions about future planning and the long term sustainability of their community. To that end, they hired WHPacific and subconsultant Shannon & Wilson to perform a Hazard Impact Assessment for the community of Atmautluak. The focus of this study is natural hazards, particularly those related to the impacts of climate change.

The plan is divided into the following sections:

1. Introduction. This chapter provides an overview of the purpose of the project, public involvement procedures, and the community of Atmautluak.
2. Hazards Identification and Vulnerability Assessment. Chapter 2 provides information about the hazards potentially present in Atmautluak and the community's vulnerability to them.
3. Data Collection and Analysis. Chapter 3 documents findings from previous studies, the contractors' site visit, aerial photography, collaboration with other agencies, and other sources.
4. Goals and Strategies. Chapter 4 focuses on methods to mitigate hazards so that the Village's viability is maintained. This includes prioritized needs, potential projects, and funding possibilities.

Public Involvement

A plan is only effective when it is relevant to the community for which it is written. To gain an understanding of the community, the residents' concerns, and the potential issues involved Suzanne Taylor of WHPacific and Eric Anderson of Shannon & Wilson traveled to Atmautluak in August 2009. They met with members of the Traditional Council, Tribal staff, and other local residents in the Tribal building and in private homes, as well as taking soil temperature readings where possible and visiting various parts of the community. Copies of the sign-in and meeting flyer are located in Appendix A: Public Involvement.

Community Description

Location

Atmautluak is located on the west bank of the Pitmiktakik River in the Yukon-Kuskokwim Delta. The community is approximately 20 miles northwest of Bethel at 60.866940 north latitude and -162.273060 west longitude.

History

Yup'ik Eskimos have inhabited this region for thousands of years; most villagers maintain the traditional subsistence and fishing lifestyle. Atmautluak was settled in the 1960s and incorporated in 1976; in 1996 the city was dissolved in favor of the traditional village council government.

Population and Housing

The 2000 US Census places the population of Atmautluak at 294; this is up from 258 in 1990 and 219 in 1980. No population data is available from before 1980. Nearly 96 percent of the population is all or in part Alaska Native. There are 64 housing units in the community, 60 of which are currently occupied. Of the four vacant, none is due to seasonal use. The average household size is just under five individuals per home; however, residents report that some households are quite crowded with significantly higher numbers of occupants.

Economy

The school, retail businesses and the village government provide cash income to supplement the subsistence lifestyle. Thirty-one residents hold commercial fishing permits. The per capita income for Atmautluak is listed as $8,500 and the median household income is $37,917. Nearly 70 percent of residents qualify as living above the poverty level.

Climate

Summer temperatures range from 62 to 42 degrees Fahrenheit; winter temperatures range from -2 to 19 degrees Fahrenheit. Atmautluak receives an average 16 inches of precipitation, with 50 inches of snowfall.

Transportation

A State-owned 2,000-foot-long by 22-foot-wide gravel airstrip is available year-round. Scheduled air service to and from Bethel is available daily. Major improvements to the runway, taxiway and apron are currently underway. Additionally, the gravel road from the airport through town is in the early stages of a road-improvement project.

Most transportation within the community is accomplished using timber boardwalks. These boardwalks keep the residents and ATVs out of the tundra, and prevent the development of very muddy travel ways on the ground. Boardwalks serve pedestrians as well as ATVs. Boardwalks in the community must be adequate to serve the four wheelers that haul waste to the sewage lagoon (Photos 5 and 28).

Infrastructure

Water Infrastructure

In 2004, the Alaska Department of Environmental Conservation (ADEC) prepared a source water assessment for the Atmautluak water system. A source water assessment is prepared to identify potential and current sources of contamination with the public drinking water supplies. In this report, they identify a single well, located under the washeteria structure, as being the source of drinking water in Atmautluak. Water is available in Atmautluak through a limited plumbing system that serves the school and teacher housing, at the washeteria, or at a water distribution faucet located near the washeteria.

Wastewater Infrastructure

Most of the black (toilet or sanitary) wastewater, as well as water from the school and teacher housing, is taken to an unlined lagoon approximately 1,000 feet northwest of the town. The lagoon is located approximately 600 feet north of the edge of the lake that borders the western part of town. The lagoon is also approximately 400 feet southeast of another large lake. There is currently no wastewater discharge permit for the lagoon on file with the Alaska Department of Environmental Conservation, and it may be assumed that the lagoon does not discharge. An organic mass was observed on the lagoon surface near the point that the honeybuckets are emptied (Photo 16). The water quality of the lagoon is unknown.

In addition to the honeybuckets, there is an insulated wastewater line that connects the village to the lagoon. The school, teacher housing, and washeteria are connected to this line. The line is primarily gravity fed with one lift station located in the central part of the town. The lines are primarily supported on biped structures placed on wooden pads on the ground. There is at least one location where the line has a significant increase in the elevation of the pipe (Photo 27). Residents report that this area has been prone to freezing, as wastewater would accumulate at this area until there was enough pressure from the lift station (located approximately 1500 feet up gradient) to provide the pressure required to force the water up the pipe.

Most of the houses in the community operate on a honey bucket system, with several honey bucket dumping stations located around the town. The material in the dumping stations is collected regularly and transferred to the sewage lagoon

Historically, the wastewater from the town, and in particular the school and teacher housing, was disposed in an unlined lagoon in the central part of town, approximately 200 feet from the primary water well (Photo 15). This lagoon is fenced to prevent access to the area.

A new, wastewater treatment plant has been constructed to treat the wastewater from the school and the teacher housing. Michael Willyerd, principal at the Joann A. Alexie School, stated that it is the intent of the school district to discharge the treated water into the old lagoon in the central part of the community, although this has not been finalized.

No studies have been identified where the thaw bulb of the former lagoon or the new lagoon has been determined. The use of the lagoons (current and historic) will potentially add warm water to the natural lakes, potentially contributing to thaw. However, the volume of wastewater is expected to be low in relation to the overall volume of the lake. If, at some time in the future, the entire community is added to the wastewater sewer system, this may increase the volume of water and potentially impact the thermal regime.

Electricity/Communication Infrastructure

The buildings in the community are served by power and telephone lines located atop wooden poles. Most, if not all, of these poles have been cut off at the base and attached to steel H-piles (Photo 4). The Village reports that this was done approximately two years ago to provide additional stability to the poles, which were beginning to show signs of frost jacking and tipping.

Two towers were observed to the west of the runway (Photo 10). Several of the guy lines appeared to be slack, which may reduce the stability of the towers particularly in high wind events.

Solid Waste Disposal

Solid waste from Atmautluak is taken approximately one mile upstream of the village for disposal. The main disposal area is a partially fenced pond located several hundred feet back from the Pitmiktakik River (Photos 13 and 14). This area is not a permitted landfill by the Alaska Department of Environmental Conservation.

The landfill is located across the river and far enough away from the village that it likely does not present a direct potential health impact to the community.

Fuel Storage Areas

Diesel for power and heat, as well as gasoline, is stored on an elevated fuel storage platform in the central part of the community (Photo 11). This structure is founded on steel piles and appears to be in good condition. Fuel lines leaving the structure generally consist of steel pipe that is placed on the ground surface with occasional wooden blocks placed underneath to provide some support. The pipes are physically unprotected from traffic and are often located within standing water (Photos 23 and 24).

Small Structures

Most of the structures in the community are built on pile foundations with an exposed air space under the structure to reduce the heat transfer between the structure and the ground. Most of the observed piles were wooden piles that were 8 to 16 inches in diameter. For a few structures, including newer houses and the fuel storage platform, steel piles are used. The area around a few of the structures was observed to be used for a storage area, which may reduce the flow of air under the structure and reduce the ability to remove heat. At least one structure had placed skirts around the piles, which may severely impact the ability to naturally remove heat from the under the structure.

A few residences, as well as most of the smokehouses or smaller structures, are founded on timbers placed on the ground surface. Several of these structures have undergone significant differential settlement (Photo 22).

The piles are generally not passively refrigerated. The only passively refrigerated piles observed were two passively refrigerated thermosphyons observed near the wastewater lift station (Photo 5).

Boardwalks and Roads

Boardwalks are used to protect the tundra and provide a walking and driving surface between most of the structures in the village (Photo 1). These boardwalks appear to be founded on shallow piles located along the length of the paths. The boardwalks were observed to undulate up to approximately six inches (primarily settlement) in isolated areas, but were generally usable without difficulty. Evidence of damage due to localized frost jacking was not observed.

In areas between the runway and the northern part of the village, a gravel surface road is present. The driving surface of the road was visually estimated to be approximately 1 to 5 feet above the surrounding grade. It is not known if the road is insulated. Community members state that the road has been undergoing some settlement in recent years.

Chapter 2 : Identification and Definition of Hazards

Climate Change

Climate change describes the variation in Earth's global and regional atmosphere over time. The impacts of climate warming in Alaska are already occurring. These impacts include coastal erosion, increased storm effects, sea ice retreat and permafrost melt.

Dr. Anthony Leiserowitz, Director of the Yale Project on Climate Change, a research scientist at the School of Forestry & Environmental Studies at Yale University, and a research scientist at Decision Research, states: "Alaska's climate has warmed about 4°F since the 1950s and 7°F in the interior during winter. The state experienced a 30 percent average increase in precipitation between 1968 and 1990. The growing season has lengthened by two weeks. Sea ice has retreated by 14 percent since 1978 and thinned by 60 percent since the 1960s with widespread effects on marine ecosystems, coastal climate, and human settlements. Permafrost melting has caused erosion, landslides and damaged infrastructure in central and southern Alaska. Recent warming has been accompanied by "unprecedented increases in forest disturbances, including insect attacks. A sustained infestation of spruce bark beetles, which in the past have been limited by cold, has caused widespread tree deaths over 2.3 million acres on the Kenai Peninsula since 1992, the largest loss to insects ever recorded in North America" (US Global Change Research Program, National Assessment, 2001)."

During the development of a design for a property in Bethel (located approximately 20 miles to the southeast), Shannon & Wilson (2009) evaluated the temperature trends for the weather station in Bethel for the purposes of developing a subsurface thermal model. The model utilized daily maximum and minimum atmospheric temperatures for the Bethel area provided by the Alaska Climate Research Center (ACRC) for the period 1923 to 2008. The record is a compilation of temperatures from the first-order weather station at the Bethel airport, BETHEL AP (PABE).

From the mean daily temperatures, Shannon & Wilson calculated annual air freezing (AFI) and thawing indices (ATI). The temperature record shows a relatively abrupt warming or decrease in the mean AFI since 1977, though it is uncertain whether the warming is the result of climate change or variability due to large-scale oscillations in atmospheric circulation patterns. Currently, the increase is being attributed to the Pacific Decadal Oscillation (PDO), a long-lived El Niño-like pattern of Pacific climate variability.

The following table summarizes the calculations:

Table 2.1 Air Freezing and Air Thawing Index Trends

Period of Record	Air Freezing Index (AFI)	Air Thawing Index (ATI)
1923-2007	Mean: 3687 °F-day Trend: -5.1 °F-day/year	Mean: 2833 °F-day Trend: 2.6 °F-day/year
1923-1977	Mean: 3885 °F-day Trend: 12.1 °F-day/year	Mean: 2771 °F-day Trend: -3.9 °F-day/year
1977-2007	Mean: 3339 °F-day Trend: 6.9 °F-day/year	Mean: 2931 °F-day Trend: 15.9 °F-day/year

A linear regression through the whole record shows a decreasing trend AFI at an annual rate of approximately 5 ºF-days per year; however, since 1977, an increasing trend is indicated in a linear regression of the data. The record shows an overall increasing trend in the ATI of approximately 3 ºF-days per year based on a linear regression; however, since 1977 the increase has been about 16 ºF-days per year.

The data set is relatively noisy compared to the relatively short period of time. Data trends over relatively short periods (10-20 years) are expected to fluctuate. However, the AFI towards the beginning of the period of record was higher than what was observed over the last 30 years. Likewise, the ATI at the beginning of the period of record was less than what was measured during the previous 30 years, indicating a general increase in the annual temperature.

It is anticipated that there will be a lag in behavior of the soil mass relative to the AFI/ATI. Or in other words, it will take time for the soil mass to reach thermal equilibrium due to minor trends in the data. As such, even if the observed data trend continues (the winters get cooler and the summers get warmer) for a short period of time, the thermal regime may be trending toward increased thaw.

The Climate Research Center at the Geophysical Institute of the University of Alaska Fairbanks has studied temperature changes over the past 60 years. Their study shows that "If a linear trend is taken through mean annual temperatures, the average change over the last 6 decades is 3.0°F. However, when analyzing the trends for the four seasons, it can be seen that most of the change has occurred in winter and spring, with the least amount of change in autumn.[1]" Table 2.2 shows the increase (in degrees Fahrenheit) in the mean seasonal temperatures in Bethel, the study community closest to Atmautluak.

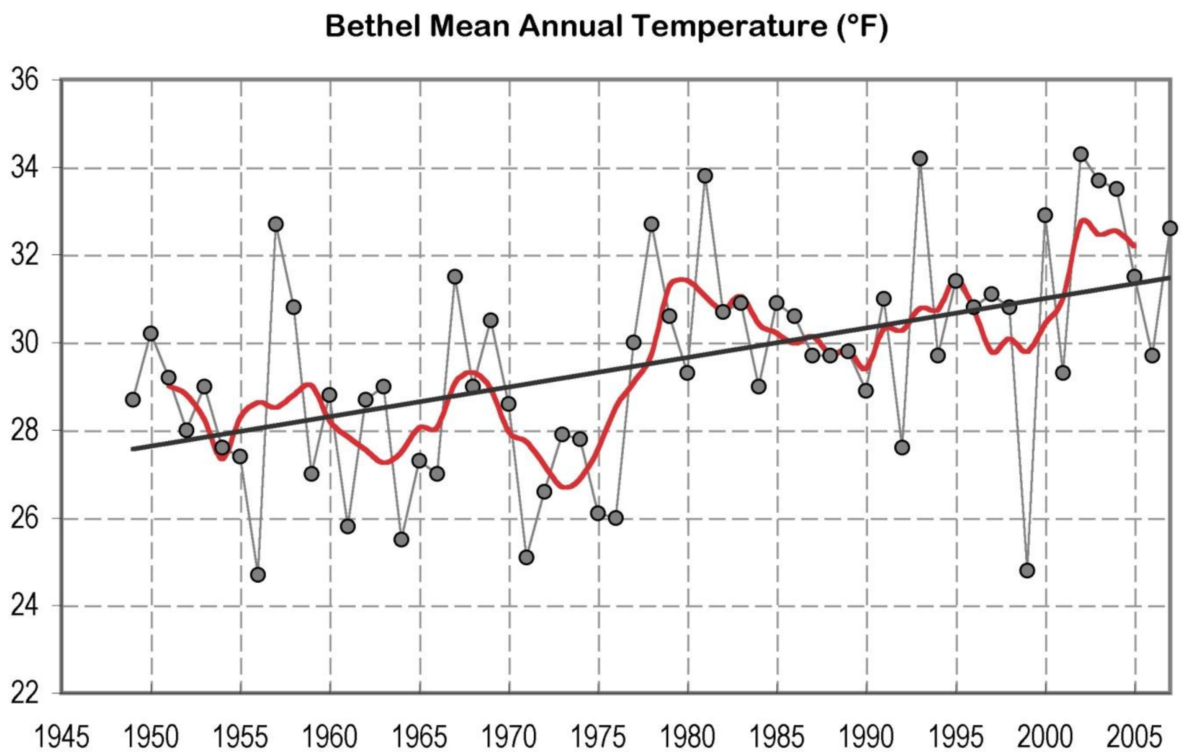
Table 2.2 Increase in Mean Seasonal and Annual Temperatures in Bethel, 1949-2009

Winter	+6.6 degrees F
Spring	+4.8 degrees F
Summer	+2.3 degrees F
Autumn	+0.0 degrees F
Annual	+3.5 degrees F

[1] Alaska Climate Research Center, Geophysical Institute, University of Alaska Fairbanks. http://climate.gi.alaska.edu/ClimTrends/Change/TempChange.html Website posted 3/9/2009, accessed 3/18/2010.

Figure 1 shows the mean annual temperature fluctuation over the same period of time.

Figure 1 Change in Bethel's Mean Annual Temperature (degrees F), 1949-2009



Source: Alaska Climate Research Center, Geophysical Institute, University of Alaska Fairbanks

Global warming is currently impacting Alaska and will continue to impact it a number of ways. These impacts include melting polar ice, the retreat of glaciers, increasing storm intensity, wildfires, coastal flooding, droughts, crop failures, loss of habitat and threatened plant and animal species. In Atmautluak, the expected impacts could include thawing permafrost, increased storm severity, and related infrastructure damage to roads, utility infrastructure, pipelines and buildings. Extremes in weather patterns could contribute to increased erosion.

The effects of climate change can potentially exacerbate each of the natural phenomena identified later in this chapter as present in Atmautluak. For example, melting permafrost contributes significantly to ground failure or destabilization of the ground in a seismic event and changing weather patterns can cause unusual and severe weather. Because of its interrelation with other phenomena, the effects of climate change will be discussed in conjunction with the other hazards rather than as a stand-alone.

Hazard Identification Process

This section identifies and describes the hazards likely to affect Atmautluak. The following sources were used o identify the hazards present in the community: the *State of Alaska All-Hazard Risk Mitigation Plan,* interviews with residents and records of past occurrences of events.

Table 2.3 is taken from the *State of Alaska All-Hazard Risk Mitigation Plan* of October 2007. The State plan identifies hazard threats by region rather than specific community. Atmautluak is identified as part of the Lower Kuskokwim REAA, one of Alaska's largest rural school districts, an area of approximately 22,000 square miles stretching from Newtok and Kasigluk in the north to Platinum in the south, Mekoryuk in the west to Kwethluk in the east. Because of the size of the region, not all the hazard information for the area applies to Atmautluak; however, the information does provide a good overview from which to begin the analysis.

Table 2.3 Hazard and Vulnerability Matrix

Hazards Affecting the Lower Kuskokwim REAA				
Flood	**Wildland Fire**	**Earthquake**	**Volcano**	**Avalanche**
Y-H	Y	Y-M	N	N
Tsunami or Seiche	**Severe Weather**	**Ground Failure**	**Erosion**	
N	**Y-H**	**N**	**Y-L**	
Hazard Identification Y: Hazard is present in the jurisdiction N: Hazard is not present in the jurisdiction				
Risk Probability L: Low probability of occurrence within the next 10 years (1 in 10 years chance). M: Moderate probability of occurrence within the next 3 years (1 in 3 years chance). H: High probability of occurrence within the calendar year (1 in 1 year chance).				

Source: *State of Alaska All-Hazard Risk Mitigation Plan*, October 2007

Previous occurrences of hazard events are a good indicator of the potential for future events. Table 2.4 lists the previous occurrences of hazard events that resulted in a declared disaster. As with the previous table, the area covered is extensive and not all hazard occurrences affected Atmautluak; however, it does present a pattern of potential issues in the region.

Table 2.4 Previous Occurrences, 1978 to Present

Previous Occurrences: Community of Atmautluak (Lower Kuskokwim REAA)				
Flood	**Wildland Fire**	**Earthquake**	**Volcano**	**Avalanche**
9-L	1-L	0	0	0
Tsunami or Seiche	**Severe Weather**	**Ground Failure**	**Erosion**	
0	4-L	0	2-L	
Number: Number of incidents declared as disasters				
Extent: L: Limited: Minimal through maximum impact to part of the community. T: Total: Impact encompasses the entire community.				

Source: *State of Alaska All-Hazard Risk Mitigation Plan*, October 2007

Identification of Hazards in Atmautluak

Based on the State's information shown in Table 2.3 and Table 2.4, consultation with Sally Cox and Erik O'Brien of the Department of Commerce, Community, and Economic Development (DCCED) Division of Community and Regional Affairs (DCRA), input from local residents and documented past occurrences, the following hazards were determined to potentially affect Atmautluak.

Table 2.5 Determination of Hazards in Atmautluak

Hazard	Present?	Basis for Determination
Flood	Yes	The Corps of Engineers (USACE) reports the flood of record occurred in 1972 and was caused by ice jam. Flat terrain and close proximity to the river make flooding an ongoing concern in Atmautluak.
Wildland Fire	Yes	Wildland fire is a threat regionally, and though Atmautluak has a great deal of groundwater, climate change is causing some areas to become drier and more susceptible to fire.
Earthquake	Yes	All of Alaska is considered to be vulnerable to earthquakes
Volcano	No	While there are several inactive volcanoes in the Yukon-Kuskokwim Delta area, none has been active more recently than the Holocene epoch.
Avalanche	No	Atmautluak's relatively flat terrain is not conducive to avalanches.
Tsunami/Seiche	No	Tsunami modeling performed by the University of Alaska Fairbanks indicates no significant threat to the community of Atmautluak despite its low elevation.
Severe Weather	Yes	Most communities in Alaska are subject to various forms of severe weather including but not limited to extreme cold, winter storms, ice fog, storm surges, heavy snows, and many others. Four previous severe weather incidents were federally declared disasters in the Lower Kuskokwim REAA.
Ground Failure	Yes	Although ground failure such as landslides is not prevalent in Atmautluak, land subsidence and ground failure related to permafrost melt are significant issues.
Erosion	Yes	Because of the makeup of soils and the location on the cut bank of the Pitmiktakik River, Atmautluak is susceptible to riverine erosion.

During the first site visit, Suzanne Taylor of WHPacific met with members of the Traditional Council and other concerned citizens. They talked about areas in Atmautluak that they observed to have changed in physical characteristics over time. These included:

- The road from the airport through town is sinking.
- The area to the northwest of that road that was previously tundra is now wet and filled with swampy grasses.
- The area to the southwest of the Tribal Building has become swampy.
- Homes on the high ground near the big lake are slanting toward the lake.
- Homes further south along that boardwalk slant toward the swampy area southwest of the Tribal Building.
- There is more water now in "Pig Lake" northwest of the school complex.
- All the lake shorelines and riverbanks seem prone to erosion; however, certain areas are more erosion-susceptible than others.

All these concerns are shown on Figure 2 Community-identified Areas of Concern. Areas of major erosion concern are marked in yellow.

Figure 2 Community-identified Areas of Concern

Analysis of Identified Hazards

Flood

Flooding can result from many causes including excessive rainfall, snowmelt, rising groundwater, and ice jams. The Division of Homeland Security and Emergency Management (DHS&EM) compiles a summary of State funds spent on disaster relief, called the *Disaster Cost Index*. No declared disasters are listed for Atmautluak specifically. The following list of previous occurrences of flood disasters in the Lower Kuskokwim region is taken from the DHS&EM's *Disaster Cost Index*, as revised in February 2009.

Lower Kuskokwim, September 4, 1990 A severe storm compounded by high tides caused extensive flooding in coastal communities of the Kuskokwim and Bristol Bay areas and along the lower Kuskokwim River. The flooding caused damage to both public and private property. The disaster declaration authorized assistance to local governments, individuals and families affected by the flooding.

04-206 06-215 2005 West Coast Storm declared October 24, 2005 by Governor Murkowski then FEMA declared (DR-1618) on December 9, 2005: Beginning on September 22, 2005 and continuing through September 26, 2005, a powerful fall sea storm produced high winds combined with wind-driven tidal surges resulting in severe and widespread coastal flooding and a threat to life and property in the Northwest Arctic Borough, and numerous communities within the Bering Strait (REAA 7), the Kashunamiut (REAA 55), the Lower Yukon (REAA 32) and the Lower Kuskokwim (REAA 31) Rural Education Attendance Areas including the cities of Nome, Kivalina, Unalakleet, Golovin, Tununak, Hooper Bay, Chevak, Mekoryuk and Napakiak. The following conditions existed as a result of this disaster: severe damage to personal residences requiring evacuation and sheltering of the residents; to businesses; to drinking water systems, electrical distribution systems, local road systems, airports, seawalls, and other public infrastructure; and to individual personal and real property; necessitating emergency protective measures and temporary and permanent repairs. On October 25, 2005, a request for a federal time extension was submitted. On December 9, 2005 a presidential disaster was declared (DR-1618) for Public Assistance for the Northwest Arctic Borough, Bering Strait REAA, Kashunamiut REAA (Chevak) and the Lower Kuskokwim REAA however, they failed to include the Lower Yukon REAA in the federal declaration. The State will write Project Worksheets for the Lower Yukon REAA under or State Public Assistance Declaration. Individual Assistance total is estimated at $209K, with 220 applicants. Public Assistance is around $3.63 million for 16 potential applicants. Hazard Mitigation total is $254K. The total cost for disaster is estimated at $5.33 million.

The Corps of Engineers states that the most recent flood event occurred in 1982 and the flood of record took place in 1972. The 1972 flood was caused by ice jamming. At that time, high water elevation signs were placed on the north corner of the Pavilla residence and on a utility pole identified as B17 located about 24 feet north of that residence. Both signs are about 18 inches above ground level. Recommended building elevation is a foot higher than that point.

Table 2.6 indicates the elevation of various community infrastructures relative to the high water elevation.

Table 2.6 Relative infrastructure elevations

Infrastructure	Feet above (+) high water elevation
Washeteria – first floor	+9.0
High School – first floor	+8.0
Grade School – first floor	+6.7
Clinic – first floor	+6.5
School generator pad	+6.1
Runway – Centerline north end	+5.0
Powerhouse – first floor	+4.8
Powerhouse fuel tanks	+1.7

Atmautluak does not participate in the National Flood Insurance Program, which is only available to incorporated cities.

Most structures in the community are built on pilings because of the permafrost, the marshy ground, and the threat of flooding.

Wildland Fire

The *State of Alaska All-Hazard Risk Mitigation Plan* reports that 600 to 800 wildland fires burn across Alaska annually, most of them between March and October. Fuel, weather and the topography of the land all factor into wildland fire behavior. Wildland fire behavior can be erratic and extreme causing firewhirls and firestorms that can endanger the lives of the firefighters trying to suppress the blaze. Fuel determines how much energy the fire releases, how quickly the fire spreads and how much effort is needed to contain the fire. Weather is the most variable factor. Temperature and humidity also affect fire behavior. High temperatures and low humidity encourage fire activity while low temperatures and high humidity help retard fire behavior. Wind affects the speed and direction of a fire. Topography directs the movement of air, which can also affect fire behavior. When the terrain funnels air, as happens in a canyon, it can lead to faster spreading. Fire can also travel up slope quicker than down.[2]

Atmautluak is not highly vulnerable to fire, as the surrounding land is quite saturated; however, lightning strikes and human-caused fires do occur in the area.

Earthquake

Approximately 11 percent of the world's earthquakes occur in Alaska, making it one of the most seismically active regions in the world. Most large earthquakes are caused by a sudden release of accumulated stresses between crustal plates that move against each other on the earth's surface. Some large earthquakes occur along faults that lie within these plates.[3] Many dangers are associated with earthquakes and those most likely to impact Atmautluak include ground shaking, surface faulting, ground failure and surface liquefaction.

[2] *State of Alaska All-Hazard Risk Mitigation Plan*, October 2007, p 105.
[3] *Ibid*, p 143.

Earthquake-induced liquefaction occurs most often in saturated soils such as are present in Atmautluak. This can cause the ground to lose strength and behave like a thick fluid. During the 1964 Anchorage earthquake, flow failures damaged facilities as far away as Seward, Valdez and Whittier. So, while no known faults are located in Atmautluak, the community could be damaged by earthquakes in more seismically active areas.

While it is not possible to predict an earthquake, the US Geological Survey (USGS) has developed earthquake probability maps that use the most recent earthquake rate and probability modes using historic earthquake rate, location, and magnitude data from the USGS national Seismic hazard Mapping Project. Figure 3 shows that according to the USGS earthquake probability model, there is a 20 percent probability of an earthquake with a magnitude of 5 or greater occurring within the next 50 years in a 50 kilometer radius of Atmautluak. That probability increases to 25-30 percent over a 100-year timeframe (Figure 4).

Figure 3 50-year Earthquake Probability near Atmautluak

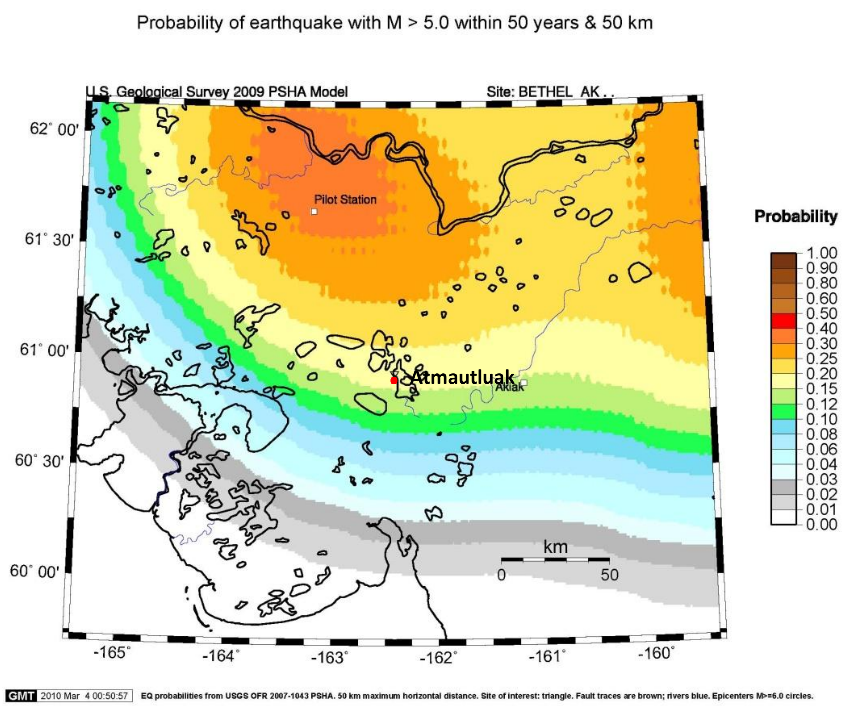
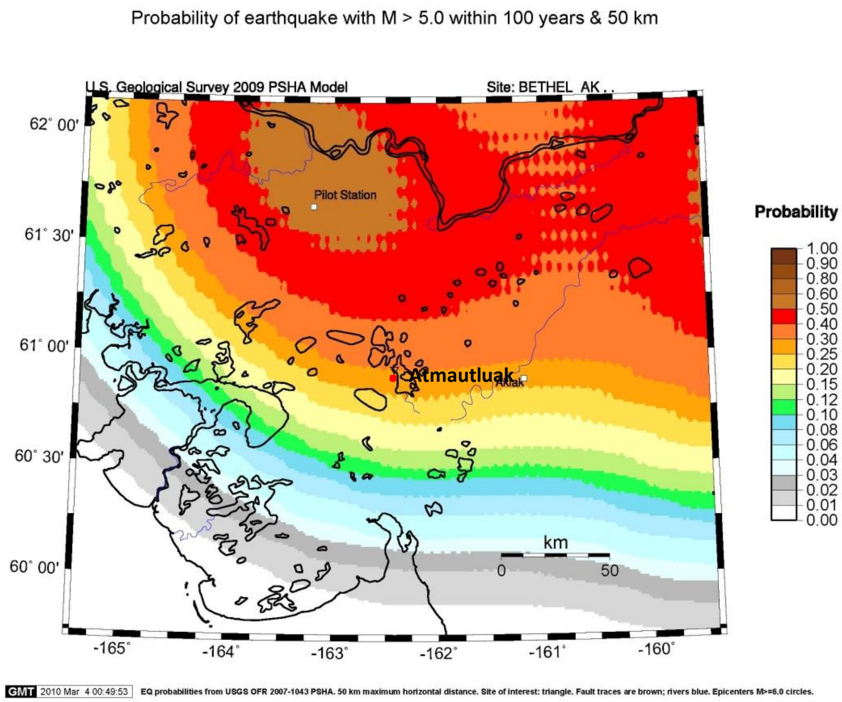


Figure 4 100-year Earthquake Probability near Atmautluak



Severe Weather

Weather is determined by the interaction of the sun, the planet's atmosphere, moisture and the structure of the planet. Certain combinations can produce severe weather that can bring about disaster events. Wind driven waves can cause coastal flooding. High winds and loose snow can produce disorienting whiteout conditions. Extreme cold, beyond 40 degrees below zero, ice fog, and heavy snows are not uncommon in various areas of the state.

Severe weather is largely defined by the community and exceeds what is considered normal for that area. Residents report that in Atmautluak there have been severe blizzards with extreme cold in which people have gotten lost and suffered frostbite or died. Strong winds have caused many roofs to be damaged or even blown off and other objects have blown away.

Ground Failure

Ground failure can occur in many ways. Types of ground failure in Alaska include landslides, land subsidence, and failures related to seasonally frozen ground and permafrost.[4] Atmautluak's flat terrain is not susceptible to landslides; however, subsidence and failures related to seasonally frozen ground and permafrost are prevalent. The thawing of ice rich permafrost is a leading cause of subsidence in Alaska; groundwater is also a contributing factor.

Ground failure related to permafrost is a significant problem in Alaska. Permafrost is frozen ground in which a naturally occurring temperature below 32 degrees Fahrenheit has existed for two or more years. Approximately 85 percent of Alaska is underlain by continuous or discontinuous permafrost… Permafrost can form a strong and stable foundation material if it is kept frozen, but if it is allowed to

[4] *State of Alaska All-Hazard Risk Mitigation Plan*, October 2007, p 183.

thaw the soil can become weak and fail.[5] Fine grained soils with high ice content are most susceptible to thaw settlement. This may be caused by climate change or because of human activity that heats the soil or removes insulating cover.

One significant cause of concern in Atmautluak is ground subsidence leading to homes tilting and apparently sinking. In addition, residents report that the ground level around their homes is lower in relation to pilings and standing pipes. One resident on the east side of the big lake said that his house was tilting back toward the lake (Photo 25). He reported that portions of the front pilings supporting the house had to be cut down to level the house (Photo 9). Additionally, the ground is more than two feet lower in relation to the standing pipes near this home than it was when he moved in.[6]

Michael Willyerd, principal at the Joann A. Alexie Memorial School in Atmautluak, discussed how subsidence is affecting the school buildings. He said that portions of the building that are settling continue to settle (Photo 32). Subsidence halts when the ground is frozen, but resumes after the annual thaw.

Photo 8 shows a small wood pad under the lift station. The pad is "floating" approximately 12 inches in the air. It is unclear whether this pad was originally at the ground surface or whether there was additional cribbing that was previously removed. No discoloration was observed on the wood, giving some indication that the wood was not in contact with the ground. Photo 30 shows the entrance stairs to the National Guard Armory located near the airport. As seen in the photo, the stairs no longer touch the approaching boardwalk, but are suspended several inches above it.

Long-time residents[7] who met with WHPacific representatives said that there has been a change in the types of vegetation that grow around the community. Many areas that were tundra-covered are now filled with marshy grasses. The land around the lake areas seems lower and there is less that can be considered "high ground" (see Figure 2 Community-identified Areas of Concern). They also reported that the floats supporting the boardwalks are sinking causing the boardwalks to undulate.

The Tribal Administrator, Daniel Waska, stated that ponding occurs and that homeowners must dig sloughs to divert water from under and around their houses. Windows and doors in the tribal building fit improperly due to subsidence and the gravel road from the airport through town is subsiding, as well.

Erosion

Erosion is a process that involves the wearing away, transportation, and movement of land. Erosion rates can vary greatly; it can be gradual process resulting from long term changes in the environment or sudden from flooding, storms or other cataclysmic events. While erosion is a natural process, human actions can influence its effects.

Erosion can be classified as coastal, riverine, or aeolian (wind-caused). With its location on the Pitmiktakik River, riverine erosion is the type most likely to affect the community (Figure 5). However, additional erosion is reported on the northern banks of the larger lakes at the south and east of town, where residents report that south winds blow across the lakes and cause wave action to erode the

[5] ibid. p 190.
[6] Henry Tikiun, personal interview, August 2009.
[7] Sign-in sheet located in Public Involvement appendix.

shoreline. Areas of particular concern are shown in yellow on Figure 2 Community-identified Areas of Concern.

Riverine erosion is caused by the river's process of constant course alteration. While a meandering stream like the Pitmiktakik River is considered more stable than a braided stream in relation to its erosion episodes, it is still subject to long-term change of its riverbed. The affects of this will be further discussed in the Observations and Potential Impacts sections of this document.

Another contributing factor to erosion, both on the riverbank and the lake shorelines, is usage. As individuals beach their skiffs and walk on the banks the rate of erosion increases due to wear.

Previous Investigations

Soils

Atmautluak is located within the physiographic province known as the Yukon Kuskokwim Lowlands, characterized by flat terrain with slow-moving, meandering rivers and numerous lakes and ponds. The soil in the area is covered by a thick sequence of Quaternary deposits, consisting of interstratified alluvial and marine sediments, generally consisting of silt and sand.

Several soils investigations have taken place in Atmautluak over the years, although there is no local repository of the soil information and the reports are scattered among local, state, and federal agencies, as well as various consultants. In August 1997, the Alaska Department of Transportation and Public Facilities (ADOT&PF) conducted a geotechnical investigation in support of runway upgrades in Atmautluak. The ADOT&PF identified Atmautluak as being in an area of discontinuous permafrost, which is different from many documents, which identify the area as being in an area of continuous permafrost. The report also states that the nearer the land is to the warming influence of the Kuskokwim River and its sloughs and tributaries, the less likely that permafrost is present.

ADOT&PF conducted their drilling program in late March, when the depth of frozen penetration is expected to be approaching its maximum depth. They drilled 17 borings near the runway to depth of approximately 10 to 15 feet below the ground surface. They reported approximately 2 to 6 feet of peat and organics overlying silt to the depth of the investigation. Massive ice was reported in several of the borings.

Nine of the borings reported soils that were not frozen, although all but one were frozen at the base of the boring. Most of the borings that were identified as having thawed soils had an unfrozen section from the base of the seasonally frozen active layer 3 to 6 feet to a depth on the order of 7 feet. Most of these borings are located in the half of the runway that is away from the village. In boring 17-96, located at the far end of the runway away from the village, 3 feet of frozen soil was reported over 8 feet of thawed, wet silt.

Shannon & Wilson conducted a subsurface soils investigation for the US Public Health Service in 1993 in support of a proposed lift station and wastewater lagoon project (Shannon & Wilson, 1993). In that study, twelve borings were drilled to depths between 12 to 35 feet. The locations are believed to be in the western to northwestern part of the community. The borings were drilled in May 1993, and thus the active layer was frozen at the time of investigation.

Figure 5 River Flow in Relation to Atmautluak

Frozen soils, peat and ice were observed in the borings to the depths explored. Ice-rich silts, organic silts and peat layers were observed in most of the borings. Ice was reported in most of the silt and peat samples observed, with the volume of the ice visually estimated to be up to 25 percent of the soil mass. Moisture contents in these samples were generally in excess of 40 percent (with a few samples near 20 percent) and several were in excess of 100 percent by weight. Massive ice was observed in several of the borings, up to approximately four feet thick. Based on the moisture content and visual ice reported in these samples, these soils are anticipated to be thaw-unstable.

Gray, trace to slightly silty, fine sand (SP) was observed underlying the silts, organics, and massive ice at depths ranging between 18 to 30 feet, where observed. In Boring DH-4, the sand was observed at approximately 10 feet below the ground surface. Samples recovered were reported to be well-bonded, with no visible ice. Moisture contents for samples of the sand were generally measured to be in the range of 16 to 30 percent.

During this investigation, subsurface soil temperatures were measured using a thermistor string installed in PVC casing in one of the borings. The results of the ground temperatures indicated warm frozen soil with temperatures ranging between 31 and 32° between depths of 5 and 30 feet. However, it may be that the soils had not returned to thermal equilibrium after the drilling and actual soil temperatures may be lower.

The executive summary for Source Water Assessment for Atmautluak (ADEC, 2010) indicates the depth of permafrost in wellhead area for the village water system is has 273 feet of permafrost.

Hydrology

Previous hydrological investigations of the Pitmiktakik River have not been identified. The team was told that Duane Miller Associates (recently acquired by Golder Associates) has done some drilling across the river for the Alaska Native Tribal Health Consortium (ANTHC). A copy of this report has been requested, but was not available at the time of this report.

Limited studies have been identified on the Pitmiktakik River and no gauging stations operated on the river by the US Geological Service were identified, so historical data is limited. In general, historic river discharge data is very limited in the area (the Kuskokwim River delta) and is generally unsuited to assess long term trends.

Brabets and Walvoord (2009) examined the impact of the Pacific Decadal Oscillation (PDO) on streamflow trends on the Yukon River. The Yukon River is significantly longer and is influenced by several factors and regions that the Kuskokwim River is not, but there is a larger time-discharge data set available for the Yukon, which allows for this type of analysis. In the Lower Yukon area, they examined sites in Ruby (approximately 350 miles north east of Atmautluak), Hughes (approximately 440 miles northeast of Atmautluak on the Koyukuk River), and Pilot Station (approximately 77 miles northwest of Atmautluak). These sites are identified by the report as being underlain by moderately thick to thin permafrost (which the WHPacific team believes to be similar to Atmautluak); but are located in hilly terrain, which is very different from Atmautluak and they are located in an area with significantly less lake area. The permafrost within the Ruby and Pilot Station watersheds is identified as mixed (both discontinuous and continuous permafrost). They also state that there has been a statistically significant increase in precipitation in western Alaska associated with the PDO.

The results of Brabets and Walvoord study indicated that Pilot Station had an increase in the winter flow and average April flow during warm PDO cycles (which we have been in since 1976. They state that as a result of permafrost thawing in the Yukon River Basin throughout the 20th Century, there has likely been an increase in recharge areas, infiltration rates, and subsurface water storage which have resulted in increased groundwater discharge to the streamflow. The report states that the increases in April (a transition month between base-flow dominated winter flow and snowmelt dominated flow) may be the result of increasing groundwater discharge to streamflow, earlier spring snowmelt runoff, and greater snow accumulation in the Interior Alaska. It is the opinion of the WHPacific study team that this information also likely applies to Western Alaska.

Erosion

From 2005 to 2009, the U.S. Army Corps of Engineers (2009) conducted a study entitled the *Alaska Baseline Erosion Assessment* to coordinate, plan, and prioritize appropriate responses to erosion throughout Alaska. This study identified communities for priority action, continued monitoring, or minimal erosion. The study identified Atmautluak as being a being a continued monitoring location, or a community that has reported significant impacts of erosion, but the impact is not likely to affect the viability of the community.

As part of this study, an erosion information paper was produced for Atmautluak. This paper, current as of August 2007, indicated that the causes to the erosion was natural river flow (assumed to include the location of the community on the cut bank of a river bend), spring breakup, melting permafrost, boat wakes, and ice jams. The paper states that in the last 10 years, three to four ice jams caused 1 to 2 feet of erosion per event and that the Pitmiktakik erodes at a rate of approximately 1 foot per year. They report that the tribal president stated that the river bank and surrounding ground used to be higher but is sinking due to melting permafrost. They also stated the nearby lake shore (west of the community) was eroding due to permafrost melting and occasional strong winds. A follow-up letter in 1999 from the Corps to the Atmautluak Traditional Council President stated that there was no apparent threat to public facilities (at that time) from erosion.

Observations and Testing

Flood

Few observations related to flooding were conducted during our site visit in August 2009, as the Pitmiktakik River was generally observed to be approximately 4 to 6 feet below bank full conditions. We did note that one residence, located near the southernmost part of the community, had a high water elevation flood marker on its treated wood foundation (photos 17 and 18).

The Corps of Engineers website states that high water elevation signs were placed on the north corner of Mrs. Pavilla’s house and on utility pole B17, which is about 24 feet north of the house. Both signs were about 18 inches above the ground; the signs were placed so that the water symbol is at the 1972 flood elevation.

Wildland Fire, Earthquake, Severe Weather

No specific observations could be made regarding these potential hazards.

Ground Failure

The WHPacific team observed the ground surface for potential evidence of ground failure or settlement (unrelated to erosion) in the area of Atmautluak during the site visit in August 2009. As part of the visit, several potential indicators of ground movement were identified, although no evidence of broad ground failure related to thawing was observed. These indicators included the apparent need for re-leveling buildings by cutting piles and cribbing, localized cracking observed near the riverbank (Photo 21), settlement under structures (such as the smokehouse in Photo 22), and the floating staircase at the National Guard armory (Photo 30).

Erosion

During the site visit in August 2009, the team observed bank erosion along the river. Daniel Nicholai took Shannon & Wilson's engineer on a boat to observe erosion along the riverbank.

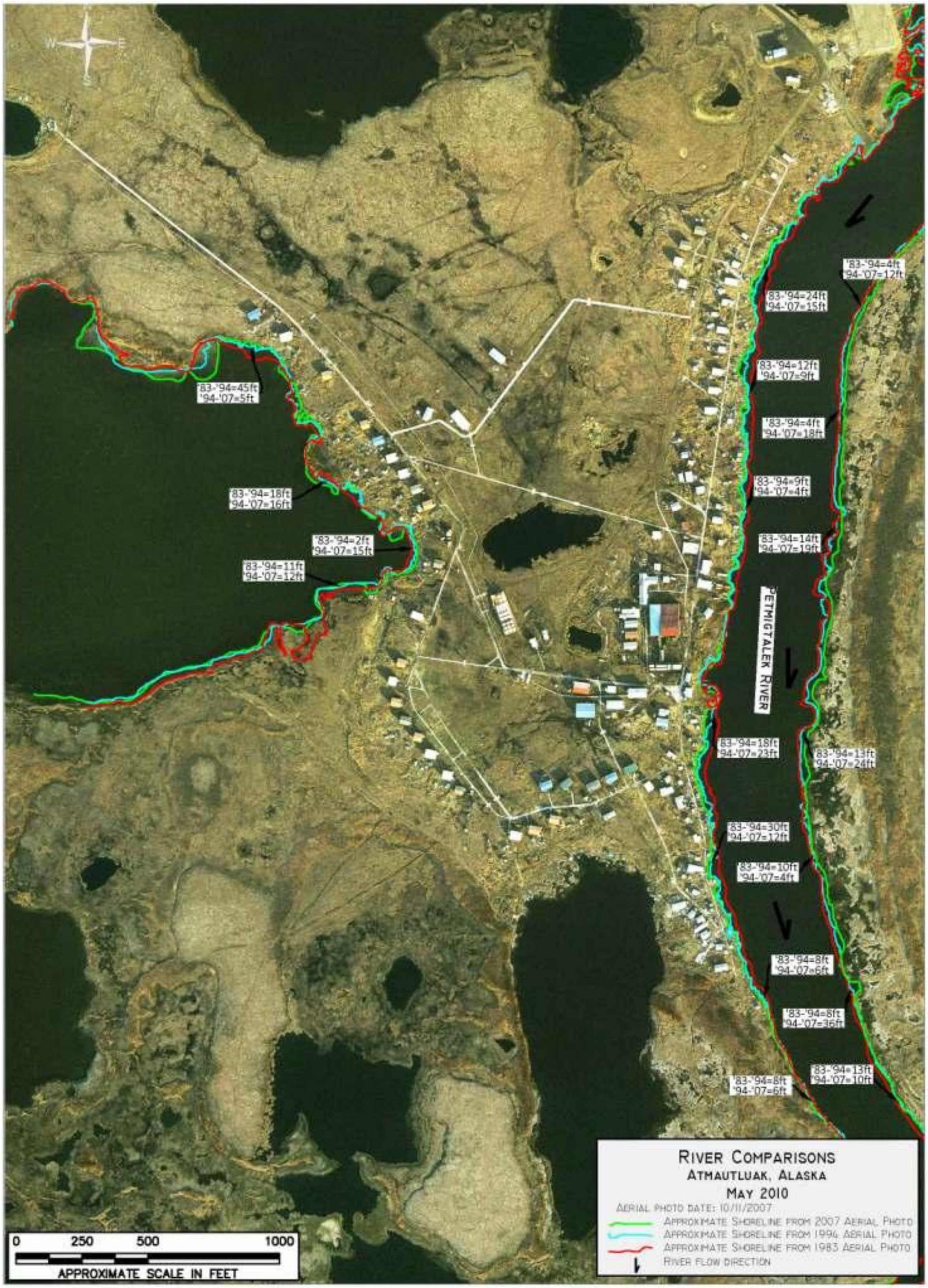
Subsequently, the team attempted to quantify the rates and potential distribution of erosion near the village of Atmautluak. To accomplish this, a bank migration study was conducted. Aerial photographs of the community taken at roughly ten year intervals (1983, 1994, and 2007) were obtained from Aerometric, Inc. There are some earlier photographs available, but the resolution is such that they may not provide an accurate basis for comparative measurement. Using the most recent (2007) photograph as a base, tracings of common structures were used to orient, position, and scale the older photographs on the base image. In general, this required a minimal amount of modification to the older images.

The river banks and lake shoreline were then traced on each photograph. The line was placed where the vegetation meets the water body. Using simple measurement tools in AutoCAD, the distance between the lines from different images were then measured to obtain the distance that the banks have moved between the images (Figure 6).

It should be noted that there are two limitations to this method. The first is that the water surface elevation at the time the pictures were taken is not known. The analysis assumes that they are roughly equal. However, if the water surface elevation was significantly higher or lower in between any two pictures, then the accuracy of the measurements would be impacted. The 1983 picture was taken in June, the 1994 picture was taken in late September and the 2007 picture was taken in mid October. It is possible that the water surface elevation in the 1983 picture was elevated due to breakup relative to the other photographs, but it is also possible that fall storms impacted the water surface elevation in the other photos. Since there is no historic discharge data available for the Pitmiktakik River, a more detailed error analysis is not possible.

The other potential source of error for this analysis is that the riverbank may be being eroded under the vegetative mat. The grasses and mass at the surface then collapses due to lack of support. As a result, the ground surface elevation may have changed significantly; the full extent of the erosion may not be determinable from aerial photography. Undercutting and vegetative collapse was occurring during the site visit in 2009. However, it would be difficult or impossible to correct for this, as there is no way to know what the conditions were when the aerial pictures were taken.

Figure 6 River Comparisons



As Based on the result of the analysis, the team observed that erosion was occurring along the Pitmiktakik River. Between the years of 1983 to 1994, the cut or concave bank (village side of the river) generally was observed to migrate toward the community on the order of 8 to 30 feet, or approximately 0.7 to 2.7 feet per year. Between the years of 1994 and 2007, the cut bank migrated on the order of 4 to 23 feet, or approximately 0.3 to 1.8 feet per year. These numbers are generally similar to what was reported as part of the Corps Baseline erosion project.

was identified in the Corps Erosion Information Paper (2007), there are several potential causes to the erosion, such as natural river erosion along the cutbank of a bend, ice impacts associated with spring breakup, boat wakes, degradation of permafrost, and ice jams. To help assess the impact of the erosion due to the bend in the river, the opposite river bank (convex or accreting) was also examined. Measurements indicated the opposite bank migrated 4 to 13 feet from 1983 to 1994 (0.3 to 1.2 feet per year) and 10 to 36 feet between 1994 and 2007 (0.8 to 2.8 feet per year). The total erosion is similar over the study period (1983 to 2007) for both sides of the river, which may be an indication that the impact of the bend may not be a major contributing factor to the overall erosion rate.

Erosion along the lakeshore to the west of the village is mixed, with some areas eroding and other areas accreting. In general it appears that the lake is accreting, but this may correspond to a decrease in the water surface elevation. The areas that are eroding appear to correspond to the areas near the residential structures, indicating boat and foot traffic, as well as the presence of the structures) may be significant factors in this area.

One notable structure, located next to the river, was identified as being impacted by river erosion (Picture 19). This structure is heated (based on the exterior heating oil tank) that appears to have been constructed with either no, or very limited, air space under the structure to remove heat. Erosion likely occurred under the house as a result of a coupled condition of thaw settlement under the structure and the migration of the river bank.

Likewise, heat in the smokehouse may have contributed to the differential movement in Photo 22. The chimney for the smoker is on the side that settled the most and that there is no significant air gap under the structure to serve as a thermal break for any heat generated by the structure. However, the area around the smokehouse appears to be lower along this section of the lake bank, thus the movement may be the result of combination of factors.

Potential Impacts

The potential impacts of many natural hazards are tied inextricably to the effects of climate change. As previously mentioned, these effects can impact each of the other potential natural hazards, making them more severe than they otherwise would be. For example, climate change can lead to permafrost thaw, accelerating the rate of ground subsidence and increasing riverbank erosion. Possible impacts will be discussed in each hazard category.

Flood

Historically, many of the floods in the area have been associated with ice jams. Information documenting the occurrence of ice jams over a long period of time was not identified. Daniel Waska stated that he was not aware of any increase in the frequency of occurrence of ice jams. Likewise, there is not much information on historical trends on the rivers in the area, including the Pitmiktakik River, so identifying the impact of climate change on flooding for Atmautluak is difficult.

Ice jam flooding will likely continue to be the greatest flood risk for Atmautluak. The community is located far enough inland that it is not anticipated that rising sea levels due to climate change will adversely impact the community. Increased severity and frequency of riverine flooding is sometimes a byproduct of climate change. Scouring during flooding events can speed up the rate of river bank erosion. In addition to damage caused by water, ice impact structural damage may occur during ice jam flooding events.

Increases in precipitation and more rapid thaws could also result from climate change. These could result in increased standing water in the village at breakup, in turn requiring homeowners to divert this water from under and around their properties. Standing water can impede emergency response and ease of transportation around the community, and could impact sewer haul efforts.

Wildland Fire

As some areas of the community become drier, possibly due to climate change, they are more susceptible to being ignited by lightning strikes and the resultant fire is more likely to spread. However, much of the community is generally wet and seems less vulnerable to wildland fire.

Earthquake

There are some seismically-related considerations that may be exacerbated as a result of warming temperatures. These include the way the ground motion attenuates through the soils, the increase in the likelihood of liquefaction or lateral spreading, and the loss of lateral stability of piles.

Earthquakes are created as movement occurs along a fault located within bedrock. When these seismic waves move through soil, rather than rock, the properties of the waves change. In general, the wave shaking will have higher displacement, velocity, and acceleration when it moves through soil relative to rock. In general, structures located over thick permafrost deposits would be anticipated to generally behave as if they are founded on rock. If thawing occurs, it is possible to see an increase in the amount that the ground shakes. However, for this to occur, there would have to be thaw on the order of dozens of feet. This is unlikely to occur over a period of several decades, thus the impact of thawing on the ground motion over the next 20 to 30 years, even if identified trends continue, is likely to be minimal.

During a seismic event, shaking can result in an increase in the porewater pressure within saturated, loose to medium dense, granular soils. This condition is common in areas where sandy permafrost has recently thawed. This elevated porewater pressure results in a loss of strength in the soil. Liquefaction has been associated with major landslides, lateral movement of bridge supports, settling and tilting of structures, and failure of retaining structures. The seismic load or demand placed on the soils required to cause liquefaction is a function of the intensity and duration of ground shaking. The duration of ground shaking is related to earthquake magnitude, and the intensity depends on magnitude, distance from the earthquake, and site response characteristics. Empirical evidence suggests that liquefaction is typically limited to soils above the 50 foot depth, with a relatively shallow groundwater table, and low relative density.

Liquefaction results in the sand behaving like a fluid. If located near the ground surface, the resulting loss of strength can cause catastrophic loss of support for spread footings for structures. Since most of the structures in Atmautluak are generally lightly loaded residential-type structures built on piles, it is anticipated that the impact of liquefaction would be minimal unless there is substantial thaw under the structure. These recently thawed materials would also likely be subject to densification on the order of several inches. Densification of dry and moist sandy materials has been observed after several earthquakes, including the 1971 San Fernando and 1994 Northridge events, particularly in hillside fill material (Pradel, 1998). Densification of liquefiable soils below the water table may also occur when subject to earthquake shaking, resulting in potential ground settlement at the site.

Locations near the riverbanks or lakes may be more susceptible to lateral spreading during a seismic event if the sand and silty sand observed in the borings thaws and remains saturated. Lateral spreading refers to landslides that are associated with gentle slopes that exhibit rapid fluid-like flow. According to Youd, Hansen, and Bartlett (2002) these movements are generally associated with soils that have loose to medium dense, non-cohesive saturated sediments. The thickness of these saturated deposits is typically in the range 3 to 50 feet for sites that have experienced lateral spreading. The soils must also meet certain gradation requirements and are generally slightly silty to silty sand and sand with trace amounts of silt. The topography of the area should meet the requirements for proximity to a free face slope or be on a gentle slope (between 0.1 and 6 percent). For locations near a slope, the free-face ratio of slopes that have experienced lateral spreading has generally been observed to be less than 20 percent. The free-face ratio is defined as the height of the slope divided by the distance from the base of the free face to the point in question. Near lakes and the river in Atmautluak, thawed sands may be susceptible to lateral spreading, which may result in movement or tilting of the structures' foundations toward the water body.

The final identified earthquake impact is the loss of lateral support for piles. When embedded in frozen ground, the pilings are relatively braced against lateral movement during a seismic event. If a portion of this lateral support is removed, it would result in increasing the magnitude of the shaking. The actual amount of this increase would be a function of the earthquake vibration, the weight and shape of the structure, and the number, size, depth and location of the piles. The impact of this loss of support on a building in Atmautluak would have to be determined on a case by case basis.

Severe Weather

The publication, *Impacts of a Warming Climate*, states that Arctic precipitation has increased by about 8 percent on average over the past century. Greater increases are projected for the next hundred years (Arctic Climate Impact Assessment, 2004). Increases and changes in storm patterns accompany climate change. Another impact mentioned by ACIA is that lake and river ice are diminishing. Later freeze-up and earlier break-up of river and lake ice have combined to reduce the ice season by one to three weeks in some areas. This can reduce the amount of time the river can be used as a road in winter, potentially increasing costs of bringing goods into the village.

Ground Failure

According to the U.S. Arctic Research Commission (2003), the permafrost underlying most of the state is the key reason why Alaskan infrastructure will be affected by a warming climate. They state that thawing poses several types of potential hazards to community infrastructure. Most of these potential hazards are associated with thawing of ice-rich permafrost, which may result in loss of strength and volume, and therefore potential settlement. In addition, a continued warming trend will likely increase the depth of the active layer.

At the point that the depth of the thaw increases below the maximum depth of the seasonal freezing front, the permafrost in the local area will become unstable. This is because it can no longer dissipate heat in a frozen condition. Heat will flow from warmer soils, now located below and above the permafrost, into the frozen soil and warming and eventual thaw will occur. This will continue until a new equilibrium is established (an increase in seasonal frost depth, the ability of the permafrost mass to dissipate heat laterally, or some other mechanism for the permafrost to dissipate heat from the mass) or the permafrost melts.

Melting permafrost may cause a loss of foundational support for buildings and other infrastructure, such as boardwalks. Any damage to the boardwalks impeded the functionality of the sewer haul system. Additionally, grade changes in the gravity sewer main could cause back up, freezing, and potentially rupture of sewer pipes.

Structures

Most structures in the community are founded on shallow piles (probably on the order of 15-25 feet. These piles are typically installed by augering holes into the subsurface. These holes are typically 1 to 2 feet bigger than the diameter of the pile (depending on pile size). The piles are placed in the holes, braced, and aligned. Sand slurry is typically used to backfill around the pile. Often, the slurry is allowed to freeze naturally, although sometimes they may be actively cooled. Once the freeze-back is found to be sufficient, the bracing is removed and the piles can begin to be loaded. The freeze-back is measured by placing thermistor strings into tubes located in the slurry and monitoring the temperatures. Given the amount of access tubes located adjacent to piles observed in the community, the team believes that this was the primary method of foundation construction in the community; although some treated wood at-grade foundations were observed. In addition, some of the steel piles may have been driven.

The bond between the pile and the frozen soil, both within the slurry and outside the slurry in the surround soils, provide the support for the structure. Both short-term and long-term performance of the structure is considered. The short-term adfreeze strength of the pile (typically used for uplift and short-term loading) is also a function of the soil temperature. If the mass of the soil warms (even if it doesn't thaw), piles embedded in the soil would undergo a reduction in soil strength. The magnitude of this decrease is a function of the temperature and the frozen material. As summarized in Weaver and Morgenstern (1981), the adfreeze strength of ice will decrease approximately 25 kPa for every 1°C increase in the soil temperature (or approximately 290 psf/°F) for temperature ranges of -1° to -5°C, which correspond to typical permafrost temperatures.

During the summer months, a deeper active layer will also reduce the load bearing and lateral resistance of pile foundations. In areas similar to Atmautluak, the soils in the active layer are often soft and wet. This provides little axial support to the pile and decreases the depth to the point of fixity and the likelihood of lateral displacement under elevated loads.

A rising in the soil temperature is also anticipated to result in an increase in the depth of the active layer. In general, as permafrost melts, the upper layers of the soil become drier and better aerated. This condition is likely to further increase the depth of seasonal thaw and the depth of the active layer.

It should be noted that even if the active layer freezes each year, increasing the depth of the active layer can create problems for buildings or utilities founded on piles. Piles that are designed for long-term axial loading are typically designed to limit the creep in the pile.

In addition to decreased capacity, increasing the depth of seasonal thaw and frost penetration may result in increasing the potential for frost jacking of pile foundations. Many of the piles supporting structures in Atmautluak were observed to be wrapped in plastic wrap. This is a common technique to reduce the bond strength between the soils in the active layer and the piles, and thus reduce the potential for jacking. However, if the active layer grows and extends below the depth of the plastic, the freezing soil can bond to the pile. If the ground begins to heave, this will increase the upward force on the pile. This may cause damage to the structure due to differential movement.

Water Infrastructure

Alaska Department of Environmental Conservation records indicate that the village gets its water from a confined aquifer from a well that is screened 272.5 to 284 feet below the ground surface. The aquifer is reported to be confined by frozen sand approximately 273 feet thick. This permafrost generally isolates the aquifer from potential surface impact. However, it should be noted that the extent of the permafrost in the area is generally unknown. Thaw bulbs associated with larger lakes or rivers will reduce the thickness of the frozen soils. If these thaw bulbs expand due to warming temperatures, the thickness of the confining layer would be reduced, potentially increasing the vulnerability of the water source to be exposed to contaminants.

The potential for flooding has been previously discussed and should also be considered when addressing the water infrastructure. The Source Water Assessment conducted in 2004 identifies the major concern with the vulnerability of the drinking water wellhead to contaminants that are transported during flooding. Any change in the flood potential in the area as a result of climate change would impact the vulnerability of the well head.

A final concern with the soils near the wellhead associated with increasing temperatures would be the potential for increased transport of contaminants within the active layer. Two primary concerns were identified. The old wastewater sewage lagoon appears to be isolated by frozen soils. However, if the depth of the active layer were to increase, there is the potential that untreated wastewater could leave the unlined lagoon and migrate near the wellhead. The other concern would be a rupture of the fuel lines near the washeteria. A spill in this area could migrate through the active layer and potentially reach the well head. The lines are located approximately 30 feet from the washeteria and lie along the ground surface, often in standing water.

Wastewater Infrastructure

The wastewater infrastructure in the community consists of the two sewage lagoons, the new wastewater treatment plant, the lift station and wastewater pipeline to the northern lagoon, and the honeybucket collection system. Currently there are two wastewater disposal lagoons, an older lagoon located near the center of town and a newer facility located northwest of the community.

At the time of our site visit in August of 2009, a new wastewater treatment plant was being completed that was planned to discharge treated water to the lagoon located in the central part of the town. We understand that the primary use of this facility, at least in the short term, is for the school and teacher housing facility. The level of treatment is not known at this time, but is assumed to meet the regulatory requirements for its purpose. However, it should be noted that the addition of any water to the unlined treatment lagoon in the middle of town might result in an incremental rise of the water temperature in the lagoon. This could increase the size of the thaw bulb associated with the lagoon and increase the potential migration of wastewater from the site.

The wastewater lines transfers wastewater from the washeteria area and potentially other structures along an insulated pipe. This pipe is generally founded on triangular supports which appear to be placed on the ground surface. These supports appear to allow for differential movement. The portion of the line downgradient the lift station to the location of the rapid change in elevation (Photo 27) functions as a force main and is not as sensitive to movement along the line. The remaining portion appears to be gravity fed. In areas of increased thaw, the support for the line may sink and create local low areas. These low areas will pool water which will have a tendency to freeze in the line. The frozen wastewater may damage the line, decrease the flow, and likely increase the maintenance requirements.

Solid Waste Infrastructure

The solid waste disposal site is near/within a pond located approximately 1 mile upstream and slightly inland along the Pitmiktakik River. Although most of the waste is residential/light commercial in nature, there is a potential that there is at least some contamination within the near surface water near the disposal area. An increase in the active layer might result in increasing the potential distance that any contamination might migrate off site. This would be a function of an increased period of time that the near surface ground is thawed and eventually could provide a thawed zone between the base of the freezing front and the top of the frozen soil. Given the anticipated nature and volume of the debris, as well as the distance to the nearest community, we do not anticipate that this will result in an increased concern for human health. However, it may result in an increase in damage to the local environmental. The disposal site currently is not a permitted sanitary landfill, so there is some concern for environmental health unrelated to climatic trends.

Transportation Infrastructure

Transportation infrastructure in the community includes the airfield, local roads, boardwalks, seasonal boat traffic, and seasonal ice-roads. The airfield and the local roads are constructed embankments. The Atmautluak runway is gravel-surfaced runway that has been constructed so that it is elevated approximately 4 to 6 feet (or more in local areas) above the surrounding ground surface. It appears that the embankment under the surface course, as well as the road section, is likely constructed of sandy silt. The heights of the embankments were designed to be thicker to attempt to contain the active layer within the fill section. According to soil borings conducted by the Alaska Department of Transportation and Public Facilities (1997), there was no insulation observed during the investigation of the existing runway.

The performance of embankments constructed on ice-rich permafrost is a function of the ability to control the thermal impacts of the embankment on the frozen soils. One indication of thermal stability of the embankment is to use the mean annual soil surface temperature (MASST). According to Zarling and Braley (1986), if the MASST of the road calculated to be above 32°F, there is no amount of insulation or fill that will prevent thaw degradation. Likewise, if the MASST is less than 32°, permafrost will tend to form or the thaw degradation of the permafrost will be stopped if the road can be designed to contain the active layer.

The MASST is calculated from the following equation:

$$MASST = T_f + (STI - SFI)/365$$

Where: T_f = Freezing temperature (32°F)
STI = Surface Thawing Index ($ATI*N_t$)
SFI = Surface Freezing Index ($AFI*N_f$)
AFI = Air Freezing Index
ATI = Air Thawing Index
N_t = N factor for thawing (1.27 to 2.01 for sand and gravel)
N_f = N factor for freezing (0.6 to 1.0 for sand and gravel)

Recent ranges in the ATI and AFI in the Bethel area are presented on Table 2.1. The ranges in N_f the N_t are from McFadden and Bennett (1991).

Assuming typical values for sand (N_t = 1.5, N_f = 0.9), a simple calculation may be done to develop a generalization of the thermal condition of the embankment. Table 2.7 summarizes these calculations.

Table 2.7 Calculated MASST for Various Conditions

Calculated Mean Annual Soil Surface Temperature						
Analysis Condition	Mean AFI	Calculated SFI	Mean ATI	Calculated STI	MASST	Stable
1923 - 1977	3885	3497	2771	4156	33.8	No
1977 - 2007	3339	3005	2931	4396	35.8	No
Increase ATI 500, Decrease AFI 500	2839	2555	3431	5146	39.1	No

Based on this simple and generalized analysis, it appears that the embankments were built with the idea that thaw under the embankment would occur. The impact of the thawing (both in terms of rate of thaw and depth) will only be increased as a result of an increase in temperature.

This analysis reflects the impact of the embankment where the depth of fill is thickest. McFadden and Bennett (1991) identify that one of the more difficult problems is at the toe of the embankment. Along the toe, they state that thickness of fill is too thin to compensate for the impact of placing fill on top of the permafrost. A thawed section can develop under the sides and toe of the embankment. This thawed zone (called a "talik") will continue to enlarge until a new equilibrium is reached. If the permafrost is ice-rich (which the study team believes to be present under the runway and roads), the shoulder of the embankment will subside into the thawed zone, causing longitudinal cracking along the embankment. The subsidence may continue until the entire shoulder slumps into the talik, removing the support from the road surface.

Most of the structures in the community are accessed using boardwalks. These boardwalks are also used by four-wheelers to transport water, wastewater (in containers from the honeybucket collection sites), and for general transportation. The boardwalks appear to be founded on treated wood planks. Many of the boardwalks are uneven (local depressions up to 6 to 8 inches. At several locations along the river, the boardwalks are cribbed using additional wood (see Photo 20). It would be anticipated that the wooden foundations may sink with time, but with a relatively shallow active layer, this would be anticipated to be minor. However, as temperatures increase and the depth of the seasonal thaw penetration increases, the wooden foundation would be able to settle more: over time, reducing the functionality of the structure.

The use of boats during the summertime is an important means of transportation for the community. An increase in the ATI would result in an increase in the time that the river would be available for boat traffic.

Likewise, the use of ice roads in the winter time provides a valuable means of transportation between Atmautluak and Bethel. McFadden and Bennett (1991) identify the Gold equations stating that the thickness of sound ice cover for a slow moving vehicle is $P<203h^2$, where P is the load in pounds and h is the thickness of the ice in inches. If some risk is acceptable, the thickness can be taken to be $P<254h^2$. If the load is going to be left standing on the ice for more than one hour, the more conservative number should be used. If there is a decrease in the AFI, it will take longer for ice to freeze to a sufficient depth. This will reduce the time available to use the ice road.

Utility Infrastructure

Utility infrastructure includes telephone and electrical lines and fuel lines. If the depth of seasonal thaw increases, it will have an impact on these utilities. Telephone and electric poles are particularly susceptible to problems. If the depth of seasonal thaw increases, this will likely result in a decrease in the lateral stability of the poles, which could result in tipping and potential failure of the poles. It would also tend to decrease the axial capacity of the pole, which could result in settlement. An increase in the depth of thaw would also result in an increased potential for frost jacking, which could lead to tipping or failure of the pole. However, the poles in the village have been recently cut off and secured to H-piles that were assumed to be driven into the permafrost. This will likely improve the long-term performance of the utility poles.

Fuel lines were observed along the ground surface. These fuel lines may appear to have been periodically supported on wood blocks, but these blocks appear to have sunk into the tundra. If the seasonal thaw depth were to increase, it is likely that the supports will continue to settle. This may result in significant loss of support of the lines and increase the chance that the lines may become damaged and/or leak.

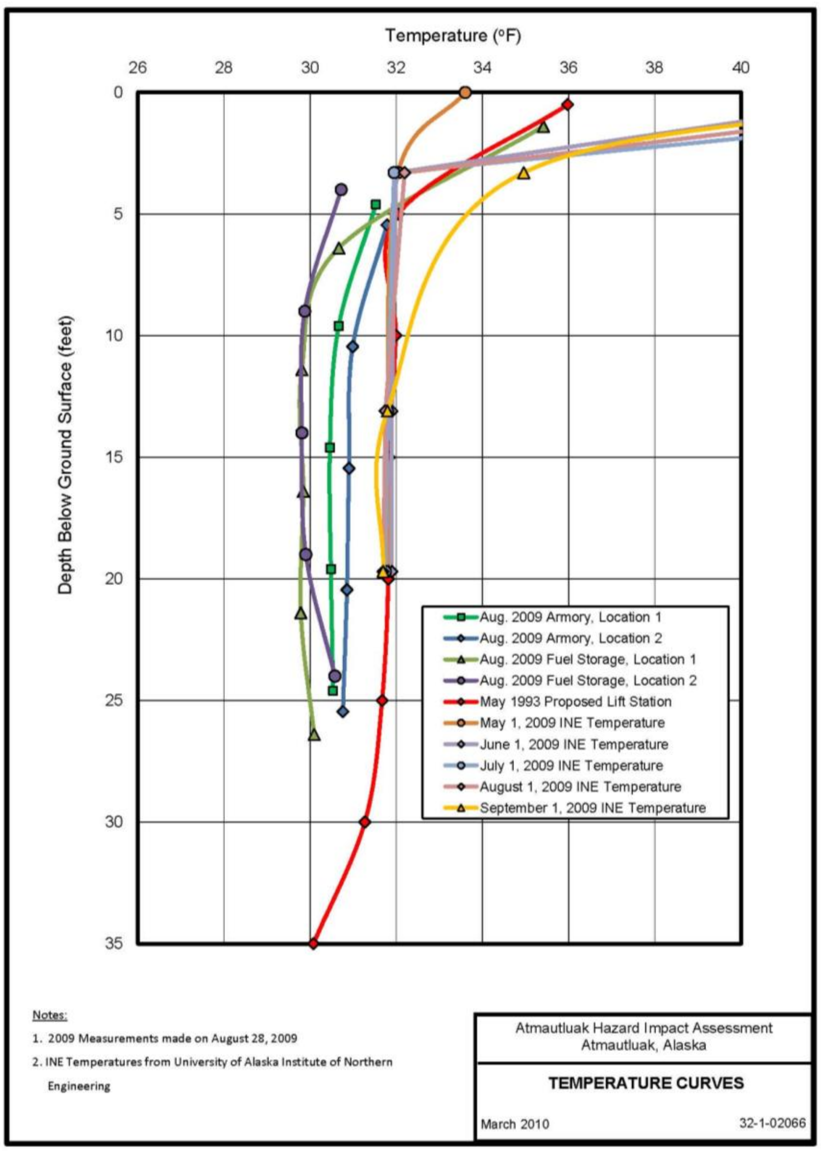
Erosion

Erosion and bank migration is occurring along the Pitmiktakik River and nearby lakes. This erosion is occurring as a result of several factors, including foot and boat traffic, ice forces, and natural river hydraulics. It appears likely that melting permafrost may also be component to this erosion. However, the erosion also has an impact on the thermal stability of the permafrost.

Thaw bulbs (in permafrost, an area of thawed ground below a building, pipeline, river, or other heat source) near water bodies are common due the physical presence and thermal properties of the water. The extent and depth of these thaw bulbs is a function of the hydraulics of the water body, the temperature of the water body, and several other factors. In general, however, the water does not come in direct contact with frozen soils unless there is a rapid change in the hydraulic characteristics of the water body. It is Shannon and Wilson's experience that flowing water rapidly thaws frozen soil. Since there is generally little direct contact with frozen soil, the direct erosion rate is generally more of a function of the hydraulic characteristics and such factors as boat traffic.

However, as erosion occurs, the edge of the thaw bulb migrates as well. This migration can be accelerated due to warming climatic trends. As the frozen material thaws, it may result in subsidence or collapse due to undercutting near the water body. This material may then be transported by the water body. It may technically be seen as the impacts of thawing soil rather than erosion, but because they are typically lumped together, we have included it as erosion in our discussion.

Figure 7 Temperature Curves



As part of their ongoing study, the Institute of Northern Engineering at the University of Alaska Fairbanks is working with the Atmautluak community to measure soil temperatures near the river bank. As reported on the temperature curves on Figure 7, the temperatures being reported are very close to 32°F to a depth of at least 20 feet. At the location of the thermistor string, depth to permafrost is probably about 5 to 10 feet, which is deeper than anticipated for most locations within the village. The location of this thermistor string (given as 60.857158°N, 162.2757°W on the Institute of Northern Engineering website) about 50 feet from the edge of the Pitmiktakik River and is likely close to the lateral boundary of the thaw bulb. This is consistent with Shannon & Wilson's observations at the site where bank collapse has occurred 10 or more feet away from the edge of the water.

WHPacific and Shannon & Wilson were not able to identify enough hydraulic and subsurface data along the river to develop a definitive statement to project the behavior of the river and larger lakes over time. In the bank migration study, changes in the approximate location of the edge of water over the past 25 years were identified. In general, migration rates along the Pitmiktakik River and the large lake to the west of the community were observed to decrease along the Atmautluak bank between the years of 1994 to 2007, relative to 1983 to 1994. The rates generally increased on the opposite side of the bank. To provide a better estimate of long-term movement along the river, the hydraulic properties of the river need to be better understood to evaluate the stability of the river bend.

The team's best estimate of structures vulnerable to erosion is depicted on Figure 8. Structures likely in danger within 10 years are labeled 2020, and those likely subject to erosion in the 25-year planning horizon are labeled 2035. These structures should be assessed for their long-term viability, whether they are structurally able to be moved or whether they should be replaced in a more secure location.

Figure 8 Future River Impact

Chapter 3 : Recommendations

In order to document and develop actions to reduce the potential effects of hazards in Atmautluak, several additional studies or actions are recommended. These actions may include additional data collection to document the need for funding prioritization, provide a basis for the design and evaluation of alternatives, or provide planning assistance to the Atmautluak Traditional Council. Table 3.1 summarizes the next steps recommended for the community as it seeks to better understand and cope with the potential effects of climate change and natural hazards. These projects are explained in greater detail in the subsequent sections of this chapter.

Table 3.1 Recommended Projects

Project	Hazard(s) addressed	Estimated cost	Possible resources	Estimated timeframe
Hydrological study	Flooding Erosion	$50K	USACE	1-5 years
Future projects should leave thermistor(s) in usable condition.	Climate change monitoring	No cost to Village	Write into contracts	Immediate and ongoing
Document active layer trends.	Climate change monitoring	$10K for equipment/ benchmarks	Staff time or school project	Immediate and ongoing
Monitor erosion in the community.	Erosion	Staff time	Staff time	Immediate and ongoing
Raise fuel lines off ground.	Ground failure /subsidence	To be determined	To be determined	1-2 years
Community land use plan	Erosion Ground failure /subsidence Flooding	$25K-35K	DCCED Administration for Native Americans (ANA)	1-5 years
Community surface drainage plan	Erosion Ground failure /subsidence Flooding	$50K (including surveying)	ADEC	1-5 years
Move or replace structures in danger from riverine erosion.	Erosion Flooding	$750K per structure for replacement	HUD NAHASDA AHFC	Phased See Figure 8

Conduct a Hydrological Study of the Pitmiktakik River near Atmautluak

Recommendation: A hydrological investigation of the Pitmiktakik River near Atmautluak would serve as a basis for quantifying the recurrence intervals of floods and to provide a basis for the evaluation of alternatives to reduce bank erosion along the Pitmiktakik. The components of the study would include the development of a flow frequency analysis to determine how much flow can be anticipated at the site for various return periods, perform water surface modeling to identify the design water surface elevation and anticipated velocities. It should be noted that this analysis is expected to be complicated by the impact of the low topographical relief, interconnected lakes (particularly during high water), and cross flow between the Pitmiktakik and the Johnson River, which may required use of more complicated, two-dimensional flow packages, rather than simpler one-dimensional flow models.

The hydrological study should also attempt to identify the impacts of ice jams on the river. Based on conversations with Daniel Waska (Atmautluak Tribal Administrator) and others, ice jams are generally associated with several of the more recent flood events. Documentation of the size, location, and frequency of the ice jams was generally not observed.

Based on the distance to the mouth of the Kuskokwim River (which the Pitmiktakik River flows into via the Johnson River), significant changes in water surface elevation at Atmautluak due to the presence (or lack of) ice or storms in Kuskokwim Bay or the Bering Sea is not anticipated. This assumption should be verified by sensitivity analysis of the boundary conditions in the water surface elevation modeling, or other accepted techniques once the base model is established.

Adopt a Requirement that any Future Geotechnical Design Study Conducted in Atmautluak Leave at Least One Usable Thermistor String Casing in the Ground

Two difficulties encountered while attempting to quantify any statistically significant changes in the ground temperature with time is the lack of a data record over time and the lack of ability to collect new data from the old thermistor locations.

When the WHPacific team conducted field observations in 2009, they attempted to measure soil temperatures at several locations (including the school, the generator platform, selected houses, and other locations) where the existing tubing could have been used to measure temperature. These could then have been compared to the original design documents. Although there would be fluctuations in the top 10 to 20 feet (plus or minus, depending on soil conditions, snow, weather, etc) resulting from seasonal changes, changes of the soil temperature at depth may allow for the quantification of soil temperature trends in the community. However, most of these existing casings were either corroded shut (if they were metal) or full of ice.

Recommendation: Future projects require at least one thermistor casing be installed and made of materials such as PVC that will not be subject to corrosion. These casings should also be filled with a non-toxic anti-freeze (such as a propylene glycol/water mixture) to reduce the potential for ice formation within the casing and allow measurements to be taken.

The actual measurement of data would also have a cost associated with it. It may be possible that academic agencies, such as the Permafrost Borehole Monitoring Program (Permafrost Health) conducted by the University of Alaska, Institute of Northern Engineering (2010), may be able to provide thermistor strings and dataloggers to measure soil temperatures versus time for academic purposes. They are currently working with the local school to measure the temperatures at one location in Atmautluak, but have only been doing so since April 2009, so the period of record is limited.

Prepare a Grid to Document Trends in the Depth of the Active Layer

As summarized by the US Arctic Research Commission (2003), the active layer plays an important role in cold regions because most ecological, hydrological, biogeochemical, and pedogenic activities take place there. The thickness of the active layer is influenced by many factors, including surface temperature, thermal properties of the surface cover and substrate, soil moisture, and the duration and thickness of the snow cover and consequentially; there is widespread variation in active layer thickness across a broad spectrum of spatial and temporal scales. To document trends in the depth of the active layer, the US Arctic Research Commission suggests several techniques, including physical probing of a graduated steel rod at the end of the thaw season (mid-August to mid-September) or installation of casings to measure temperature. They suggest conducting measurements on plots or grids that vary between 10, 100, or 1000 meters on a side. These studies would have to be conducted seasonally over a period of many years (preferably decades) to develop a dataset that provides a statistical basis for documenting subsurface change with time. In order to allow a higher degree of accuracy in the measurements over time, we recommend that benchmarks be installed. The benchmarks should be stationary devices such as rebar embedded in the permafrost (wrapped in plastic in the active layer to help reduce frost jacking) that would help ensure that the basis of measurement remains the same.

Recommendation: Document trends in the depth of the active layer. The collection of annual data and the long term record keeping would be the challenges associated with either method. The driving of the graduated probe would likely be the easiest to set up, as it would just involve driving a metal rod to the point that it encounters difficult conditions. The measurement of subsurface temperatures using a thermistor string would involve the installation of PVC casings below the active layer, which may require mechanical assistance (such as a power auger or drill) and the casing should be filled with a non-toxic anti-freeze to reduce the formation of ice within the casing. However, the temperature data would provide much more data to determine what is happening over the area.

The costs for this project could be reduced if the school (or other local) group was willing to undertake the data collection and record keeping as part of a long-term science project.

Monitor Erosion in the Community

Recommendation: One of the recommendations of the US Army Corps of Engineers *Alaska Baseline Erosion Assessment* is to measure the top of the riverbank from points set throughout the community. They state that the ideal locations for the points are corners of buildings or other steadfast infrastructure. This data should be archived electronically at the Village and shared with appropriate agencies as they work with the community.

As an alternative, they state that a study of aerial photography could be conducted (similar to what was conducted in this study.) While the aerial photograph study can give a broad overview of what is happening at this location along the entire riverbank, the nature of the erosion (undermining prior to collapse of the vegetative mat) and the variation in water surface elevation creates inaccuracies in the interpretation of the data. The ideal study would include a bank migration study based on aerial photographs that were supplemented and validated with physical measurements.

Evaluate the Potential for Placing the Fuel Lines on Vertical Support Members

Fuel lines were observed on the ground surface in a wet environment. This condition could lead to corrosion of the lines and potential leakage. If there was an increase in the active layer or an increase in water at the surface resulting from a change in climate, this condition could be exacerbated. In addition, the piping could come loose from support of the underlying wooden bracing if it were to settle as a result of increased soft or wet soils.

Recommendation: An engineering study should be performed to evaluate alternative piping support or other foundations that would provide adequate support and would keep the pipe out of the water to reduce the potential for corrosion.

Develop a Land Use Plan for Future Community Development

Based on observations and analysis, Corps documentation, and comments from the community, the area along the Pitmiktakik River bank and developed areas along the big lake in the west are eroding.

Recommendation: The WHPacific team recommends that the community adopt a development plan that identifies locations outside this area as preferred locations for new housing or other community building facilities or development. The relatively open area approximately 1000 feet north-north west of the school is one potential area. The identification of the area best suited area could be accomplished by a geotechnical survey of undeveloped areas. The areas that were best suited would be areas with thicker organics, less surface water, and shallower active layers (shallow seasonal thaw). Areas that are shown to contain thawed soil under the active layer (most likely near water bodies) should be avoided.

As part of this planning document, the community should consider requiring that new construction increase the depth that wood or steel piles are embedded as required to address anticipated changes in the thermal regime over the life of the structure. As an alternative, the use of a passively or actively refrigerated foundation could be considered. The specific increase or use of refrigerated foundation, if selected, would be determined by the design professional associated with the project.

Given the potential for movement, the village should consider banning at-grade treated wood foundations, if it has not done so already. Although these foundations could be re-leveled periodically, it is anticipated that the level of maintenance will be relatively high. Likewise, the use of adjustable foundations should be carefully considered prior to use to ensure that potential settlement under the structure over the life of the structure is within acceptable limits.

To increase awareness of the issue and provide a basis for community review of the design process, the design professional could be asked to provide an analysis of the impacts of long-term climate change on the structure. The analysis would evaluate the potential impact of a changing climate on the structure according to certain assumptions (which they would then provide). The analysis would indicate how potential impacts would be addressed so that the structure will meet safety and serviceability requirements over its design life. This statement is not intended to be a certification of performance, but to serve as a mechanism to call out the specific assumptions made and confirm that the impacts of a changing climate were considered. The assumptions could then be easily reviewed and discussed as part of the development of the design. To be most effective, these assumptions should be part of the preliminary design package, so potential changes could be made during the development of the design.

Develop a Community Surface Drainage Plan

Daniel Waska stated that community members were aware that if water was observed ponding under their house, they needed to dig a ditch to drain the water, or it could cause problems with their foundations. This is generally true.

Recommendation: WHPacific/Shannon & Wilson team recommends that an engineering study be performed to identify the potential for increasing this practice community wide. Several areas of ponding were identified within the boundaries of the community and in general, the tundra was wet. If a simple surface drainage system could be installed that would drain some of this surface water into nearby rivers or lakes, this would likely increase the depth of frost penetration, resulting in decreasing the depth of the active layer and potentially decrease permafrost degradation. As part of this study, the design professional will have to examine whether or not this activity would be allowed under current wetland provisions of local, state and federal law and what would be required to mitigate environmental and regulatory considerations.

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Appendix A: Public Involvement

Atmautluak

Hazard Impact Assessment

Project: *Atmautluak Hazard Impact Assessment* ***Date/Time:*** *8/27/09*

Location: *ATC Tribal Building* ***Reporter:*** *Suzanne Taylor, WHPacific*

Participants:
Suzanne Taylor, WHPacific
Eric Anderson, Shannon & Wilson
Daniel Waska, ATC
Members of the Atmautluak Traditional Council and other interested parties:
Oscar Nick, Carl Pavilla, Moses Pavilla Jr., Henry Tikiun Jr., Morris Mochin

Information gained from individuals prior to meeting:

Kimberly Daniel works with the utilities. She stated that "ground is becoming more marshy." She believes that the water is rising in Big Lake near her parents' home, or that the ground is subsiding.

Melvin provides maintenance for the school.

Pat Desmit at LKSD is the contact regarding the school building.

Daniel provided photos of flooding in the community.

Meeting was not formal. Individuals came and went. The following comments were made:

Many areas that were tundra are now marshy grass. Land around lake areas seems lower. There is less high ground.

South winds blow across Big Lake and erode the bank near the houses (three on the end).

Daniel remarked that boardwalk floats are sinking and the gravel road is subsiding into the ground.

Council members helped to mark up the community aerial photo to show areas of concern.

After the meeting and the following day Suzanne and Eric spoke with others in the community.

Michael Willyard, principal at the school, said that areas of the building that are settling seem to continue to settle. They stop when the ground is frozen, but then continue to go down after the thaw.

Henry Tikiun, Sr. lives in a house by Big Lake. He said that the ground has settled 3 to 4 feet. He said that it tilts toward the lake. Henry indicated that they had to cut the pilings at the front of the house to level the structure. He said that the standing pipes beside the house are exposed about 2 to 4 feet more than when he moved in in 1981. He said the ground seems to be getting lower every year.

Henry thought that Bethel Housing Authority was responsible for leveling houses. (This does not seem to be borne out.)

Atmautluak

Hazard Impact Assessment

Public Meeting
Sign In Sheet

August 27, 2009

Name	Address/City/Zip	Phone	e-mail	resident Since
Oscar Nick	Atmautluak	553-9[illegible]		1960
Carl Pavilla	Atmautluak	553-5511	angut007@yahoo.com	
Moses Pavilla Jr	Atmautluak	553-2146	mpavilla_jr@yahoo.com	
Henry Tikiun Jr	Atmautluak	553-5849		
Morris Mochin	Atmautluak	553-5349		'69

Informational Meeting

When? Why?
Where?

Location: Tribal Building
Date: August 27, 2009
Time: 3 pm

Hazard Impact Assessment

Your questions, comments and input are important!

This will be an informal meeting to talk about this planning project and its benefit to the community. All are welcome.

Come and provide input:

- What natural hazards threaten the community?
- What are the facilities that need to be preserved in case of a natural disaster?
- What can you tell us about the problems Atmautluak faces due to natural hazards?

WHPacific

If you have questions contact:

Suzanne Taylor
WHPacific, Inc.
907.339.6570
staylor@whpacific.com

Appendix B: Photo Log

Photo 1: Village of Atmautluak illustrating typical boardwalk and grass

Photo 2: Timber piles supporting generator and electrical support pad. Note ponded water near piles. We attempted to measure temperature in black PVC pipe, but the water in the casing was frozen at a depth of approximately 2 feet.

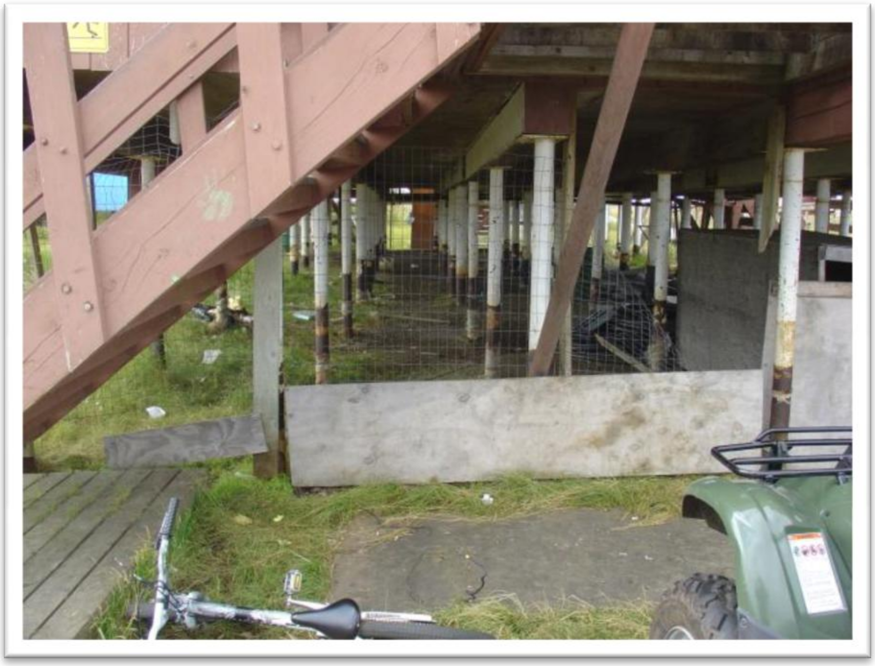

Photo 3: Steel pipe piles under washeteria/water supply building. Piles are wrapped with plastic sheeting near the ground surface, which may be to reduce potential frost jacking. This may indicate relatively shallow piles.

Photo 4: Timber utility posts have been cut off near the ground surface and attached to H-piles. We understand this work was completed within the last few years.

Photo 5: Passively refrigerated thermosyphons near the sewage lift station, sewer line in background.

Photo 6: Blocking under school.

Photo 7: Plastic-wrapped wood pile supporting the school building. We attempted to access the pipes alongside the piles to measure temperature, but either could not remove the caps or they were blocked by ice at about two feet below the surface.

Photo 8: Floating footing under lift station. Given the lack of discoloration that would be an indicator of embedment, the pad may have been supported on blocks in the past, rather than being an indication of settlement.

Photo 9: Repair of distressed residence near north end of village. Note blocking between pile top and support. The diagonal member appears to provide lateral support to the entryway.

Photo 10: Tower located between sewage lagoon boardwalk and runway. Note the slack in the guy lines.

Photo 11: Pile support fuel storage facility.

Photo 12: Settlement around wrapped steel pile under the fuel storage area.

Photo 13: Ponding water in solid waste disposal area.

Photo 14: Temporary disposed refuse on riverbank near solid waste facility.

Photo 15: Old wastewater treatment lagoon in central part of town. New school wastewater treatment plant in background.

Photo 16: Primary wastewater treatment lagoon located approximately one-half mile northwest of the main body of the village.

Photo 17: Proximity of house to Pitmiktakik River at south end of Atmautluak. Note high water elevation mark on structure.

Photo 18: Close up of high water elevation mark on residence. Note apparent timber (non-pile) foundation.

Photo 19: Riverbank erosion under existing structure. Building is being supported, in part, on fifty-five gallon drums.

Photo 20: Riverbank erosion near existing structures and undermining boardwalk.

Photo 21: Riverbank erosion. The grass mat likely reduces the rate of erosion, as it provides some insulation against thaw and resistance to water flow and wake erosion.

Photo 22: Smoke shed undergoing settlement near lake on north side of village.

Photo 23: Fuel piping along ground in central part of community

Photo 24: Fuel piping along ground in central Atmautluak

Photo 25: Homes next to big lake on west side of Atmautluak. These homes are reported to slant toward the lake.

Photo 26: Utility pole on H-piling support with slack guy wires

Photo 27: Sewer pipe to sewage lagoon northwest of town.

Photo 28: Fencing around sewage lagoon slumps as land subsides.

Photo 29: Houses and other structures on the Pitmiktakik River bank.

Photo 30: Stairs at National Guard Armory no longer reach ground level.

Photo 31: Measuring soil temperatures under Tank Farm.

Photo 32: Blocks level and support school building.

Photo 33: Ponding in gravel road from airport through town.